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TDF-1, THE FRENCH BROADCASTING SATELLITE (TDF-1, SATELLITE FRAN--ETC(U)
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# TDF-1, THE FRENCH BROADCASTING SATELLITE /31*

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Abstract:

After recalling the objectives and the implementation framework of the preoperational direct broadcasting satellite program, the author discusses the role and mission of the TDF-1 satellite. This is followed by a general description of the satellite which is scheduled for launch at the end of 1984 using an Ariane launcher. The paper also covers the organizational and industrial structure set up for the program and its follow-on developments.

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Studies in the field of satellite broadcasting have been conducted in France for a number of years. The early ones concerned principally the technological research and development and in the particular, the 12 GHz power amplifiers as well as the high-power and high-output solar generators, two pieces of equipment which differentiate a direct television satellite* from a conventional telecommunications satellite. The feasibility studies led to the conclusion that the technological advances accomplished and the experience acquired in the earlier communications satellite programs permit the direct development of a preoperational system (in which a satellite meets all specifications necessary to an operational system but is not duplicated in orbit by a backup satellite).

*Or direct television: the prescribed term of broadcasting covers the broadcasting of images as well as of sounds or other signals intended "to be received directly by the general public."

The similar objectives of their broadcasting satellite programs as well as the advantages to be derived from cooperation led France and the Federal Republic of Germany in 1978 to examine the possiblities of a bilateral program. At the October 1979 Franco-German summit the decision was taken to undertake such a program. Consequently, the French minister of industry* and the minister of research and technology of the Federal Republic of Germany in April 1980 signed aanco-German convention on technical and industrial cooperation in broadcasting satellites.

*CNES, Programs and Planning Directorate

The bilateral prog-am covers the development, manufacture, and the launching of two satellites of identical design, TDF1 and TV SAT, which differ mainly in the transmission antennas adapted to the French and German coverage. These two satellites are to be placed in orbit late in 1984 by the European launch vehicle ARIANE. A third satellite will be preassembled on the ground and ready to receive

*Numbers in right hand margins indicate pagination in the original text.

the elements specific to the French or German mission to serve as a backup in case of a breakdown in one of the two first ones.

The Franco-German industrial consortium set up to produce the satellites of the program is thus supposed to be able to provide for the future manufacture and sale of the satellites of this type in export markets being developed.

Role and Mission of the Satellite /32

The mission specifications have been defined by the national agencies, Telediffusion de France (TDF) and the Deutsche Bundespost (DBP) German Postal Service which will operate and use each satellite in conformity with the provisions established by the World Administrative Satellite Communications Conference (Geneva, 1977), which set up a very precise plan of which the principal data for France are given in Table 1.



Table 1

| | |
|---|---|
| Orbital position of the satellite | 19$^{\circ}$W |
| Precision of orbital position | $\pm$ 0.1$^{\circ}$ |
| Opening of transmission antenna | 2.5$^{\circ}$ x 0.98$^{\circ}$ |
| Coordinates of center of beam | 2.6$^{\circ}$E, 9$^{\circ}$N |
| Orientation of beam | 160$^{\circ}$ |
| Transmission frequency band | 11.7 - 12.1 GHz |
| Channels | 1, 5, 9. 13, 17 |
| Maximal equivalent radiated isotropic power | 64 dBW |
| Polarization | right circular |
| Width of broadcasting channels | 27 MHz. |

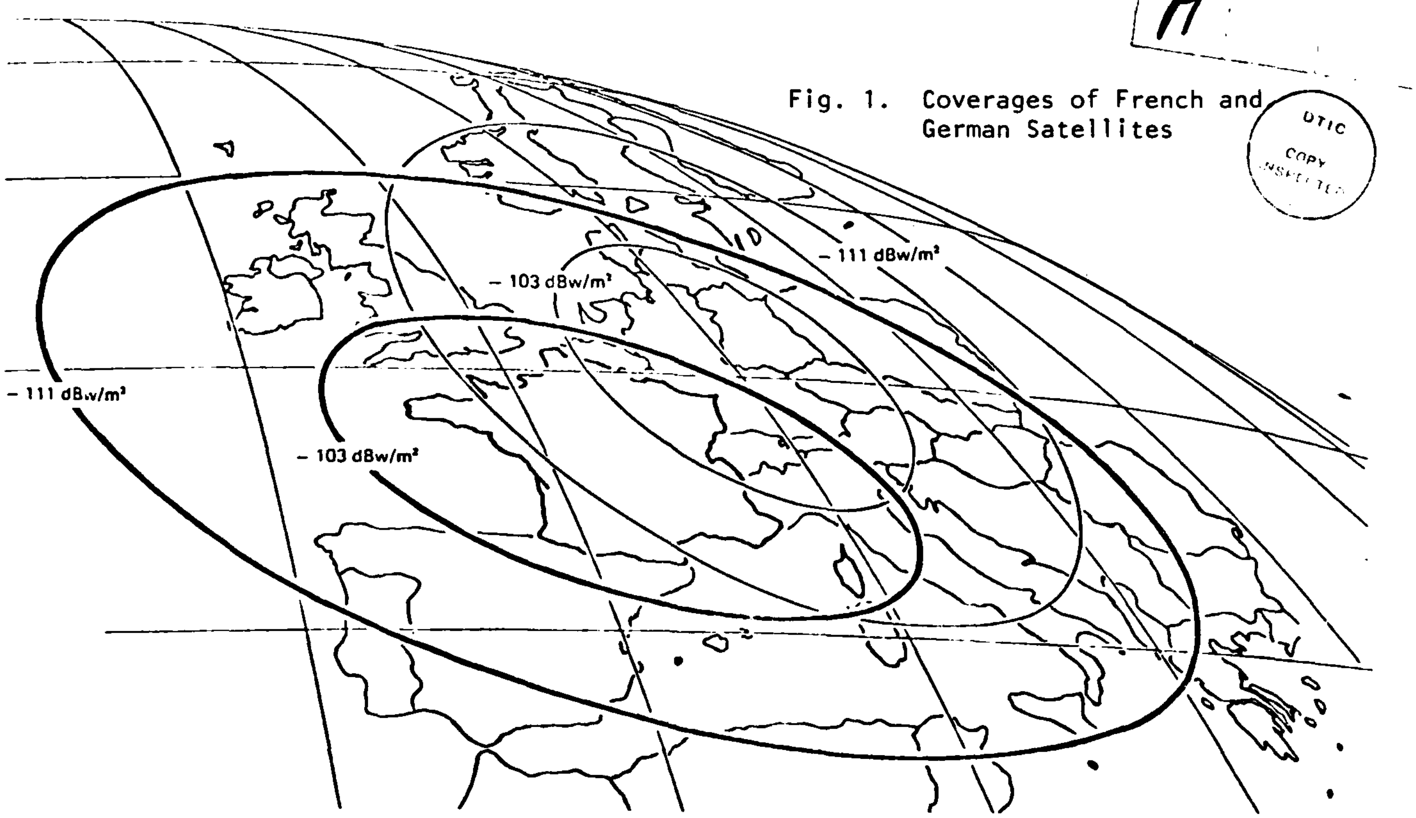



Fig. 1. Coverages of French and German Satellites

## Broadcasting Capacity

The satellite is supposed to be able to transmit simultaneously three broadcasting channels of the five assigned by the 1977 Geneva Plan (with the capacity to adapt to a later version with five active channels); a broadcasting channel is typically composed of a television program (image and sound) modulating in frequency a carrier wave of the 12 GHz band, but it can be composed of an equivalent message which does not cause any greater interference.

## Coverage Zone

Fig. 1 (curve 103 $dBw/m^2$) indicates the coverage of the French satellite allowing for the half-power opening allocated for the elliptical beam ($2.5^\circ \times 0.98^\circ$) emitted by the satellite antennas. Thus, and if the satellite transmits with the authorized power, good reception free of perceptible noise and interference is assured over the entire national territory* with a receiving installation meeting the characteristics set by the World Administrative Satellite Communications Conference (factor of merit 6 dB/K, antenna about 90 cm). Beyond the half-power opening, there is no sharp drop in the emitted signal and, with a receiving installation with better performance, or by tolerating a drop in quality from time to time, the French satellite transmissions will be able to be generally picked up in a number of neighboring countries. It is thus, for example, that with an installation six times more sensitive than the standardized installation (factor of merit of 14 dB/K), or an antenna double the diameter and a more sensitive receiver), the French programs ought to be received often up to the 111 $dBW/m^2$ contour in Fig. 1.

*And, a priori, over the whole elliptical coverage; but the plan established by the World Administrative Satellite Communications Conference guarantees the absence of perceptible interference only within national frontiers.

## Continuity of Service and Life

Continuity of service is a particularly strict requirement of the broadcasters. In satellite broadcasting, any malfunction could have serious consequences, deprive the whole country of a program for a time, for example, and no longer a small part of the country for a rather short time, as is the case for a breakdown of an earth transmitter.

That is why all technical resources are being employed to assure a very high level of reliability of the satellite. That is why also care has been taken to define a system which will assure a "nominal quality" even in the simultaneous presence of possible unfavorable conditions (aging of equipment, misalignment of the satellite, coverage limit, heavy precipitation...). That is why, finally, no operational system is established without a backup satellite in orbit which is capable of immediately carrying on.

The reliability of the various equipment and the installed redundancies produce for the preoperational satellite a calculated probability of reliable operation of three channels of 0.8 at the end of the nominal life of seven years (the life is set a priori by the quantity of propellants carried on board to assure its station keeping and its attitude during that period).

## Description of the Satellite

As indicated above, the TDF1 and TV SAT satellites are defined to meet the specifications of the French and the German missions (simultaneous broadcasting of three channels with characteristics of the Geneva Plan), while allowing for the capacity to adapt and expand to missions with a full five-channel capacity or to export missions.

The satellite now has a "conventional" configuration with stabilization in three axes and a heliotropic north-south solar generator.

It is a modular design which has been adopted, and the satellite appears like an assembly of various modules for the principal functions (Fig. 2):

--antenna module
--communication module
--control module
--propulsion module
--solar generator module.

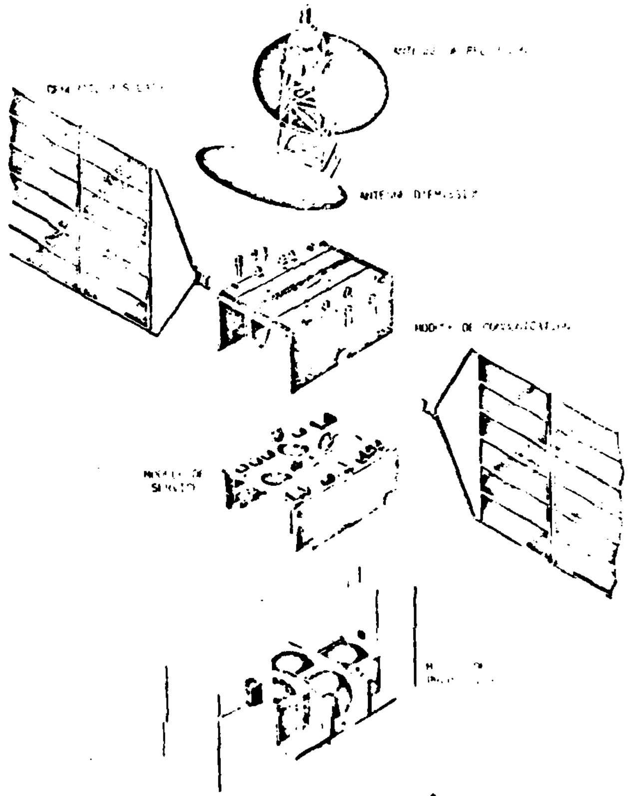


Fig. 2. TDF 1, Modular Design

a. Solar generator b. Receiving Antenna c. Transmitting antenna d. Communication module e. Control module f. Propulsion module

Even after integration of the various modules, the inside equipment of the satellite remain accessible by removal of the access panels. Fig. 3 shows the satellite in the launch configuration and Fig. 4 shows the satellite in the on-station configuration with the solar generator deployed.

Per form 50



A

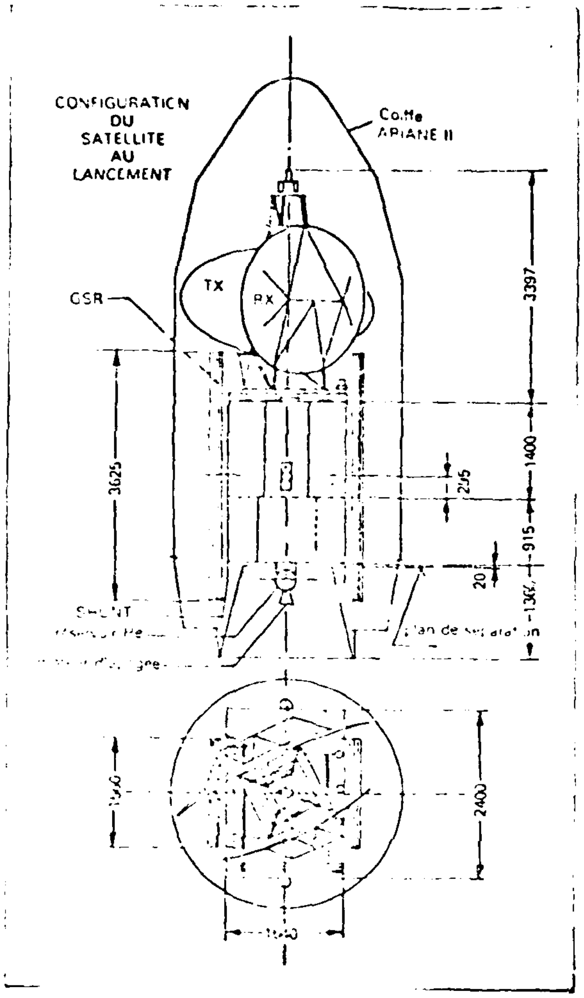
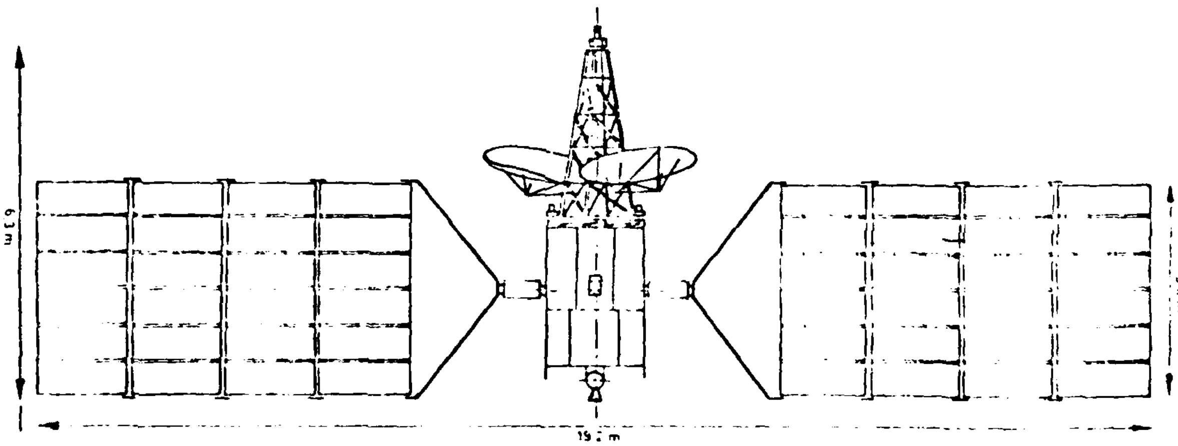



Fig. 3. Satellite in launch configuration

a. *Configuration of satellite at launch*
b. Cone ARIANE II  c. He tank
d. Apogee motor  e. Separation plane

Fig. 4. Satellite in on-station configuration



## Antenna Module

The TDF-1 is equipped with different antennas for transmission and reception. The antenna reflectors are fixed on an antenna platform; a tower supports the transmission and reception power supply systems (as well as the 2-GHz telemetry-remote control antenna). The 12-GHz transmission antenna is an elliptical antenna 2.4 x 0.9 meter fed by a multi-source network. Its orientation, which is precise

to about 0.05° (the body of the satellite being stabilized to about 0.4°), is obtained by a fine-aiming mechanism driven by the signals delivered by an RF sensor.

The 18 GHz receiving antenna is circular with a 2.1-m diameter, powered by a single-source system. Its orientation precise to about 0.2° is obtained by an aiming mechanism controlled by the error signals of the transmission antenna.

Communication Module (Fig. 5)

Wide-band receiver

The receiving function is performed by a wide-band receiver composed of two redundant circuits. Each circuit is composed of an input filter, a mixer, an intermediate-frequency amplifier, and a local oscillator for which the same pilot provides, after multiplication, the two frequency translations. The total equivalent noise temperature at the receiver input is 2000°K.

Amplification of signal power

After separation of the channels by a demultiplexer composed of filters coupled by circulators, amplification is provided by solid-state devices (field-effect transistors) and some 250-Watt TOPs. The dimensioning of the electrical power system permits the simultaneous functioning of three power circuits. Redundancy is provided by six power circuits which can function on the five allocated frequencies, one of them being equipped with two circuits in total redundancy and with one power switch. The redundant design facilitates the evolution of the satellite toward a generation of satellites with five channels active simultaneously.

**TDF1:**
**charge utile**

Fig. 5. TDF-1: PAYLOAD

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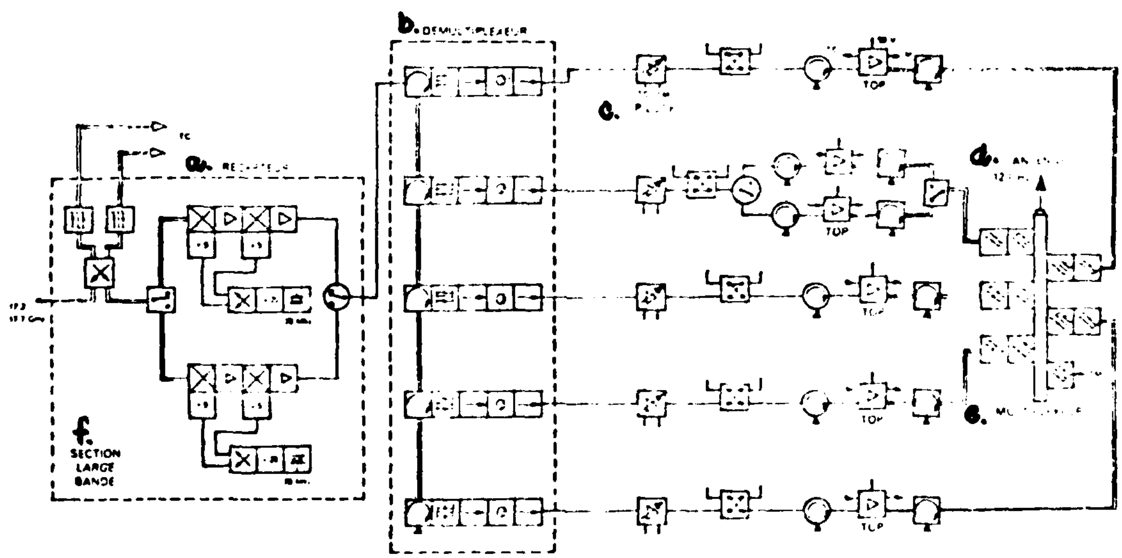


a. Receiver b. Demultiplexer c. Pilot d. 12-GHz antenna e. Multiplexer
f. Wide-band section

### Output multiplexer

The combination of the channels at the output is effected by means of a reflection guide multiplexer which combines the five channels and the telemetering signals toward the antenna.

## Control Module

### Attitude and orbit control

The attitude and orbit control subsystem is based on the principle of three-axis stabilization with on-board angular momentum.

It uses a redundant "one-axis" wheel, solar sensors, infrared earth sensors, gyros, a bi-propellant (a technology also retained for the apogee motor, which resulted in a unified propulsion system) and attitude control electronics.

### Power package

In view of the range of power, a sequential digital shunt design has been adopted; it permits very good efficiency, low dissipation, and large currents.

To best meet the mission demands, the power distribution is effected over two separate busbars: the main busbar toward the payload (high power during periods of insolation) and the permanent busbar toward the vehicle during all the phases, including eclipses.

A battery feeds the subsystems of the vehicle during the launch, transfer, and eclipse phases.

### Telemetering, remote control, localization

Telemetering, remote control, and localization operations are possible.

--In the Ku band (broadcasting service band) in normal operation on station and in the backup mode, using the antennas of the payload and transmitters and receivers in "cold" redundancy;

--In the S band, during the transfer stage up to station-keeping and in the backup mode, using a quasi-omnidirectional antenna placed at the peak of the tower and coherent transponders (in "hot" redundancy for the receivers).

## Solar Generator Module

The solar generator of the TDF-1 is of the lightened (carbon fiber) rigid solar generator type.

The dimensions of the panels are optimized to obtain the maximum active surface as a function of the volume available inside the ARIANE nose cone, and they are 1.6 x 3.6 m.

The power available at the end of the life (seven years) for the nominal four-panel model per wing is more than 3 kW.

The expansion potential of this generator permits up to nine panels per wing.

For the transfer orbit, the systems studies resulted in the partial deployment of one panel per wing. /36

Propulsion Module

All the propulsion maneuvers (apogee, station taking, station keeping, and attitude control maneuvers) are effected by a single propulsion system or Unified Propulsion System (SPU--French abbreviation), hereinafter UPS).

This UPS uses the Symphonie technology for the 400-N thrusters of the apogee motor and for the 10-N thrusters used for all other needs. Four tanks (capillary retention) are used to store the fuels (MMH and $N_2O_4$); two high-pressure tanks serve to store the helium necessary for pressurization. The adaptation of the ARIANE 2 capacity to the ARIANE 3 capacity can easily be accomplished by adding a cylindrical segment to the fuel tanks and by increasing the walls of the pressurization tanks.

Thermal control

In view of the great dissipations of the communication module and of the power subsystem, only the use of caloducs [meaning unknown] permits minimizing the height and the weight of the satellite.

The communication module is thermally decoupled from the control module and propulsion module in order to minimize the interactions between these modules and to permit modular control.

The great variations in dissipation in the communication module also result inthe use of replacement charges (heaters) when the traveling-wave tubes are not in operation. Moreover, certain specific equipment require automatic heat control.

Structure

The principal characteristics of the structure are its modularity; three modules make up the structure of the body of the satellite (excluding the solar generator and the antennas):

--the communication module
--the control module
--the propulsion module.

Weight Breakdown (in kg)

| | | | |
|---|---|---|---|
| Repeater | 114 | Power supply | 84 |
| Antennas | 92 | Solar generator | 150 |
| Thermal control | 75 | Cabling, various | 68 |
| Structure | 172 | Dry satellite weight | 946 |
| Propulsion | 107 | Fuels + pressurization | 1004 |
| Attitude control | 48 | Launch adapter | 47 |
| Telemetry, remote control | 36 | Launch weight | 1997 |

Energy Breakdown (end of life in Watts)

| | Solstice | Equinox |
|---|---|---|
| Bus | 590 | 590 |
| Thermal control | 140 | 280 |
| Battery charge | 20 | 95 |
| Payload | 2125 | 2125 |
| Total consumed | 2875 | 3090 |
| Generator power | 3060 | 3312 |
| % margin | 6.4 | 7.2 |

Dimensions of the TDF-1 Satellite

--Under payload fairing

- total height
- height of body
- width

--On station

- total wing span
- solar panel area
- total height

The structure is designed to be able to accommodate a communication module of a height and weight suited to missions of greater capacity.

*State and Industrial Organization*

The Franco-German convention on technical and industrial cooperation in broadcasting satellites signed in April 1980 established the broad lines of the common state and industrial organization set up since then.

On the governmental side, a Board of Directors (chaired alternately by a French representative and a German representative) with equal representation (C.N.E.S. [National Center for Space Studies] and T.D.F. [Broadcasting Agency of France], for France, and the Ministry of Research and Technology and Ministry of Posts and Communications for the Federal Republic of Germany) defines the general directions of the program and gives the necessary directives to a joint project directorate in Munich, Germany (French projects director, German assistant director) and is charged with the control and follow-up of the production of the satellites.

On the industrial side, a Eurosatellite Franco-German consortium with equal representation has been constituted to develop and produce the satellites, by the Société Nationale Industrielle Aérospatiale (SNIAS) and Thomson-CSF on the one hand, and Messerschmitt Boelkow Blohm (MBB) and AEG, on the other.

A joint industrial team is set up in the MMB establishment in Munich. Overall coordination of the satellite project is provided by this team under the direction /37 of Thomson-CSF.

State and industrial cooperation is to be continued for production of future satellites (for French and German needs, for export). The terms and conditions of that cooperation have been set by a codicil to the Franco-German Convention signed in September 1981.

At the national level, a program committee has been established by a CNES-TDF Convention. This committee is to provide liaison between the agencies, CNES and TDF, those in charge of the preoperational TDF-1 program and of the preparation of national programs which might be decided on later.

For the TDF1 preoperational program, this commitee is to take into account in particular the strictly national elements of the program:

--setting up control and connecting stations
--control of the launch by ARIANE
--monitoring operations during the life of the satellite.

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